Image Analysis for Radiation Oncology via Probabilistic Approaches

Stephen M. Pizer, Kenan Professor, University of North Carolina

Abstract: Treating cancer by radiation requires analysis of medical images, and that analysis deeply benefits from probabilistic modeling. The imaging takes place at three times: diagnosis, treatment planning, and treatment deliveries. 3D images at diagnosis and planning time, together with 1 or more 2D projection images at treatment deliveries are used. I will explain how medical decisions are guided using segmentation of target objects and objects at risk, registration of images taken at different times, and shape information in diagnosis. I will show how probabilistic machine learning of means and eigenmodes of shape variation, eigenmodes of image appearance variation, regression matrices on shape, and optimization of posterior distributions are useful for the segmentation and the registration. I will also show how classification or hypothesis testing based on object shape can aid diagnosis. This talk will survey at a high level the applications, the object representations, the image analysis methods, and the statistical approaches that are useful for accomplishing the objectives. It will motivate the methods of statistical shape analysis to be presented in the second talk on Friday, entitled PCA-like Analysis of Shape via Composite Principal Nested Spheres Applied to Skeletal Representations (S-reps).

Co-authors: S Chang, EL Chaney, C-R Chou, X Liu, G Mageras, JS Marron, D Merck, J Rosenman

PCA-like Analysis of Shape via Composite Principal Nested Spheres Applied to Skeletal Representations (S-Reps)

Stephen M. Pizer, Kenan Professor, University of North Carolina

We designed a form of object model that exactly and completely captures the interior of most non-branching anatomic objects and simultaneously is well suited for probabilistic analysis on populations of such objects: nearly medial, skeletal models. I will first mathematically define these models in continuous 3-space and then form discrete representations by a tuple of spoke vectors. After sketching means of fitting skeletal models into manual or automatic segmentations of objects, I will specify means of modifying these fits to produce correspondences of spoke vectors across a training population of objects based on tightening the derived probability distribution. These discrete skeletal models live in an abstract space made of a Cartesian product of a Euclidean space and a collection of spherical spaces. Based on this understanding and the way objects change under various rigid and nonrigid transformations, a method analogous to principal component analysis called *composite principal nested spheres* will be seen to apply to learning a significantly more efficient collection of modes of object variation about a new and more representative mean object than those provided by other methods.

Co-authors: Sungkyu Jung, Dibyendusekhar Goswami, Xiaojie Zhao,
Ritwik Chaudhuri, James N. Damon, Stephan Huckemann, J.S. Marron